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Roman military settlements in the Northwest of the Iberian Peninsula.

The contribution of historical and modern aerial photography, satellite imagery and airborne LiDAR.

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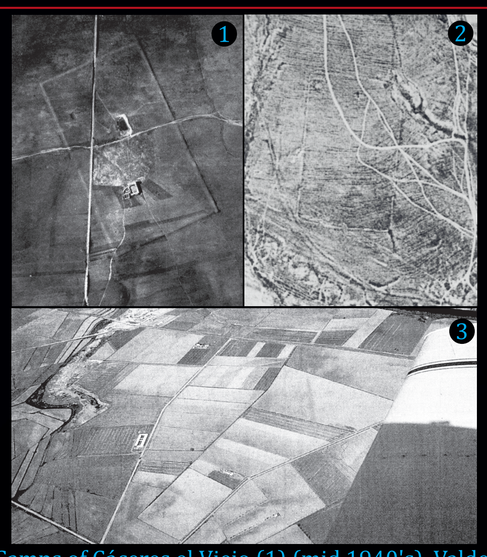
The origins of a discipline

The relationship between Roman military archaeology and aerial photography is not new in the historiographical context of the Iberian Peninsula. In the early 20th century J. R. Mélida commissioned to the incipient Spanish military aviation a photographic flight over Numantia (González Reguero 2007: 239). Some of the camps of the famous scipionic siege could have been then identified. The military get involved in the aerial surveying of several archaeological sites in the following years, including the republican camp of Cáceres el Viejo (Almagro Basch 1943: lam. I).

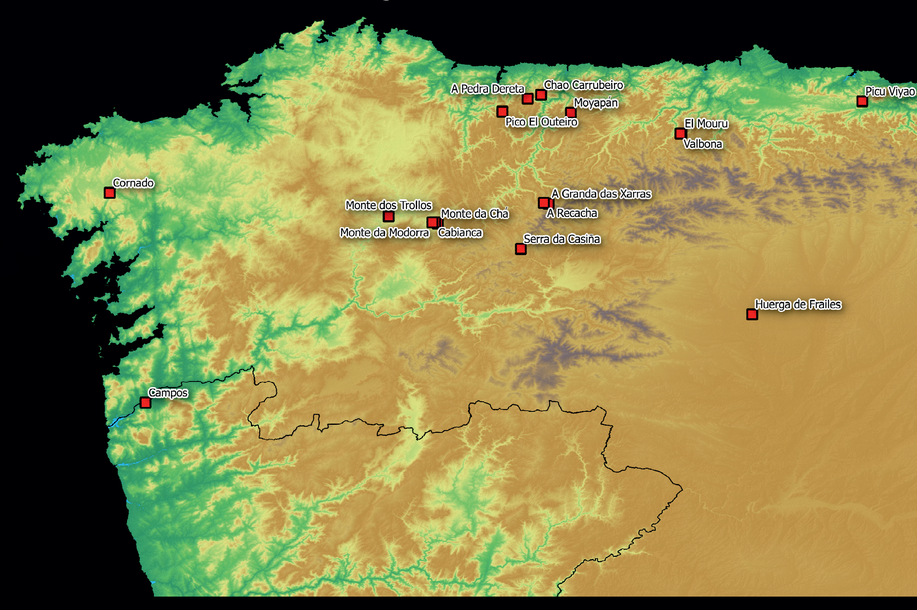
After World War II the Spanish government commissioned to the USAF two stereoscopic flights covering the whole country (1945-6 and 1956-7). The second one, named "Vuelo General de España Serie B" (USAF AST6 54-AM-78), was repeatedly employed by archaeologists and it allowed the discovering of new camps as those of Castrocalbón (Loewinsohn 1965) and Valdemeda (Sánchez-Palencia 1986).



Camps of Cáceres el Viejo (1) (mid 1940's), Valdemeda (2) (1956) and Villalazán (3) (early 1990's)

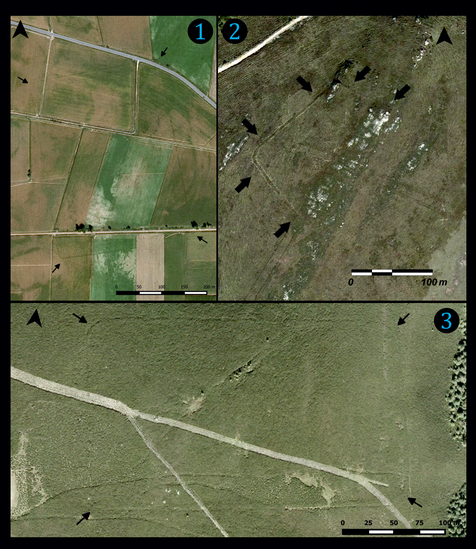
During the decades of 1990 and 2000 aerial photography also played an important role in the revival of the Roman military archaeology in Spain. The planning of flights sensitive to the archaeological methodology allowed the discovery of new camps as well as the detailed study of some other had previously revealed (Del Olmo 1995; García-Merino 1996; Peralta 2011).

The popularization of aerial and satellite photography, geographic information systems (GIS) or airborne LiDAR opens now a new phase in which low-cost specific methodologies start to proliferate (Menéndez, González et al. 2013). However, its application in Iberian Roman military archaeology is still at a very early stage.



Location of Roman military sites studied for this contribution

Former experiences: different techniques, different approaches



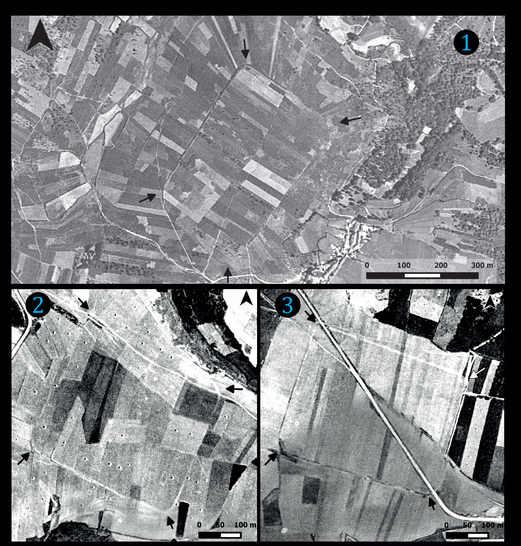
Some camps detected using recent PNOA flights: Huerga de Frailes (1) (2006), Moyapán (2) (2006) and A Granda das Xarras (3) (2008)

The use of PNOA aerial photography.

Since 2004, the *Plan Nacional de Ortofotografía Aérea* (PNOA) aims to obtain digital aerial orthophotos of the entire Spanish territory with a resolution of 25 or 50 cm and with an annual temporal resolution adapted to each autonomous region (http://pnoa.ign.es/). While these data are freely available in Spain. In Portugal a comprehensive coverage of digital orthopohotos with 50 cm resolution was recently made available by the Portuguese Geographic Institute (www.igeo.pt) through web-mapping services.

The open access to PNOA data has allowed us to develop a systematic survey method, especially effective in the mountainous regions of Asturias and León without dense vegetation canopy. Sometimes the ancient ramparts are still visible and can be remotely detected, other times the trenches can be tracked due to the differential accumulation of moisture. After locating those potential sites we planned their archaeological field survey.

This way we discovered many *castra aestiua* in the past: Moyapán, Huerga de Frailes, El Mouru, Valbona, A Granda das Xarras, A Rechacha, A Pedra Dereta, Chao Carrubeiro, Picu el Outeiro, Serra da Casiña o Picu Viyao (González, Menéndez et. al. 2008, 2011; Menéndez, Blanco et al. 2011).



Some camps detected after reviewing USAF 1956-7 historical aerial photography: Cornado (1), Monte da Modorra (2) and Monte da Chá (3)

The contribution of historical aerial photography.

The PNOA also offers a Digital Photo Library service in which several photogrammetric flights from 1930's onwards can be located (http://fototeca.cnig.es/), including the two already mentioned USAF flights . This information is open access, but sometimes the flights have not been accurately orthorectified. In Portugal, similar materials can be obtained by request from the *Secção de Fotografia Cartográfica* of the Geographic Institute of the Portuguese Army (https://www.igeoe.pt/).

The employment of historical flights introduces a significant diachronic factor in the study of Roman military sites, since many of these camps have been hidden or destroyed in recent times mainly due to the impact of anthropic activity. That is the case of Campos, razed during the construction of an industrial park. Reforestation plans or the introduction of heavy machinery in agricultural works have also damaged the camps of Cornado, Monte dos Trollos, Monte da Modorra, Cabianca and Monte da Chá in a different degree (Gago and Fernández 2015; Costa et al. *forthcoming*).

Towards a new low-cost methodology

In areas that are usually densely forested, the identification of archaeological features is still very problematic (Doneus et al. 2008). The introduction of Airborne LiDAR has helped to overcome this problem because of its unique capability to penetrate vegetation canopies, making it possible to document the underlying topographic surface and identify any cultural remains on it (Opitz and Cowley 2013).

The identification of archaeological features on LiDAR-derived DEMs is very dependent on visualization techniques that can enhance our perception of anthropogenic features. Different methods have been proposed, from simple hillshading to more complex calculations like Sky View Factor (Kokalj et al. 2011) or Local Relief Models (Hesse 2010). These visualization techniques have been compared (Bennett et al. 2012; Chalis et al. 2012; Štular et al. 2012) and the results confirm that no single visualization method outperforms the rest in all types of terrain. Therefore, a combination of these techniques is the only way to obtain the maximum volume of information on potential archaeological features.

Among the more effective are the trend removal procedures (Hesse 2010; Štular et al. 2012) based in the theoretical assumption that when a smoothed surface is compared to its original, local small-scale topographic features are contrasted from large-scale landscape forms.

A CASE STUDY: IDENTIFICATION, CHARACTERIZATION AND ASSESSMENT OF A RAZED ARCHAEOLOGICAL SITE AT CAMPOS (PORTUGAL)

1. Documentation:
While studying the XVIIth century fortification system in the spanish-portuguese frontier, references to the existence of fortified sites were detected in Campos (Blanco-Rotea 2015: 478-485), in the southern bank of the river Minho.

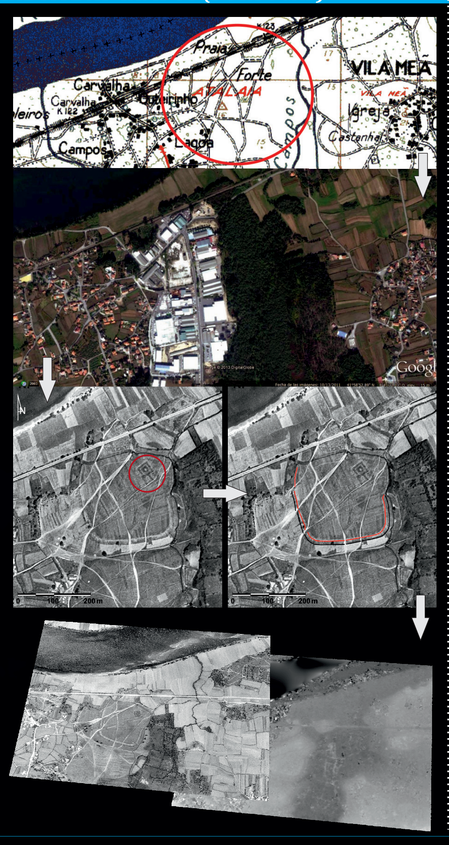
2. Toponymic analysis:
Two interesting micro-place names where detected reviewing old topographic military maps: *fort* and *watchtower.*

3. Extensive and intensive field survey:
Althought we surveyed the area, no archaeological trace could be detected. The construction of a industrial park in the 1980's has completely transformed the whole place.

4. Photointerpretation of historical aerial photos:
This situation led to the adquisition of historical aerial photographies to the Portuguese Army. The photointerpretation of these data from the 1940 and 1950 decades allowed the detection of a square structure with a southern appendix which was very similar to some modern watchtowers and fortlets previously documented in the Minho valley. However, it was surrounded by a bigger enclousure, quadrangular in shape and with no parallels in modern times.

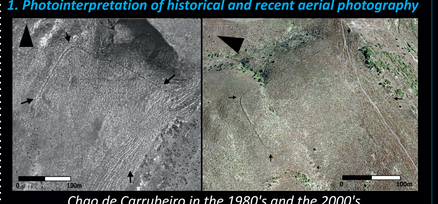
5. Morphological analysis:
A closer study of the enclousure revealed that it was composed of two different alignments, being white-coloured the inner perimeter and darker the external one. The accumulation of moisture was probably showing the existence of an ancient *agger* and *fossa* defensive system. The playing card layout of the structure also resembled a Roman camp, but its northern defences were gone long time before the 1940's. Perphaps they were destroyed during the construction of the modern age fortlet.

6. Photogrammetric analysis:
Since the archaeological structures are completely razed, the only way to obtain further valuable archaeological information is employing Structure from Motion (SfM) photogrammetric techniques on the historical aerial photos. In this way, we can obtain new carthographic data, like Digital Surface Models (DSM) and orthophotos. From there, we have made new photointerpretation (2D, 3D and stereoscopic) trying to identify the various positive and negative microtopografies of the camp.



DETECTION AND STUDY OF ROMAN MILITARY CAMPS IN MOUNTAINOUS AREAS

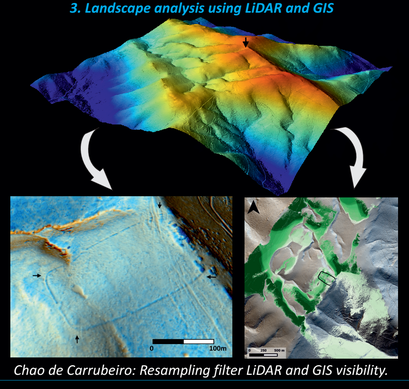
1. Photointerpretation of historical and recent aerial photography



Chao de Carrubeiro in the 1980's and the 2000's

2. Intensive field survey

3. Landscape analysis using LiDAR and GIS



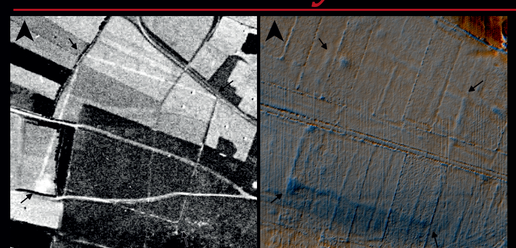
Chao de Carrubeiro: Resampling filter LiDAR and GIS visibility.

In Spain there is an almost complete LiDAR coverage (http://www.ign.es/PNOA/vuelo_lidar.html), with all the data freely available. The LiDAR data are already classified, so we only have to isolate the ground points from which we have obtained a Digital Terrain Model (DTM). In most of the cases we have used the hillshade as a visual technique, although in some cases we have applied other more complex and advanced visualization techniques, such as the Resampling Filter available in SAGA GIS software, a trend removal technique, that allow us to represent local small-scale elevation differences, similarly to Local Relief Models (Hesse 2010).

In order to understand the landscape in greater detail, we have combined airborne LiDAR data with historic and modern aerial photos and satellite imagery, which proved to be a valuable method as each technique revealed different features, making it possible to maximise the results (Crutchley 2009). When necessary, we have used Structure from Motion (SfM) photogrammetry to orthorectify and georeference historical aerial photos from the 1940s and the 1950s, allowing us to obtain new cartographic data, namely Digital Surface Models (DSM) and orthophotos (Pérez et al. 2014).

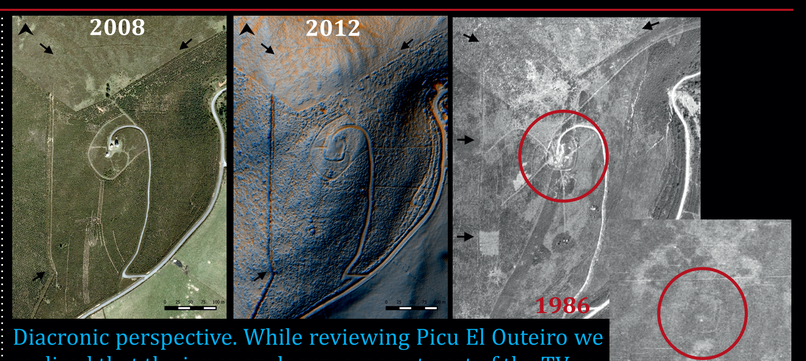
Thanks to these techniques we will be able to develop new morphological and landscape analysis for the study of Roman military sites by using GIS tools (Costa 2015).

Other case study sites

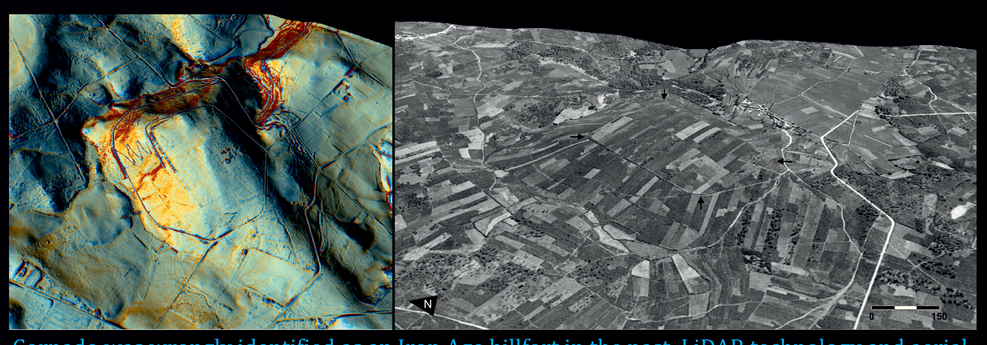


Agricultural work is a big issue in plain areas. The smallholding farming will erase the traces of Cabianca camp in few years as it happened before with Monte da Modorra.

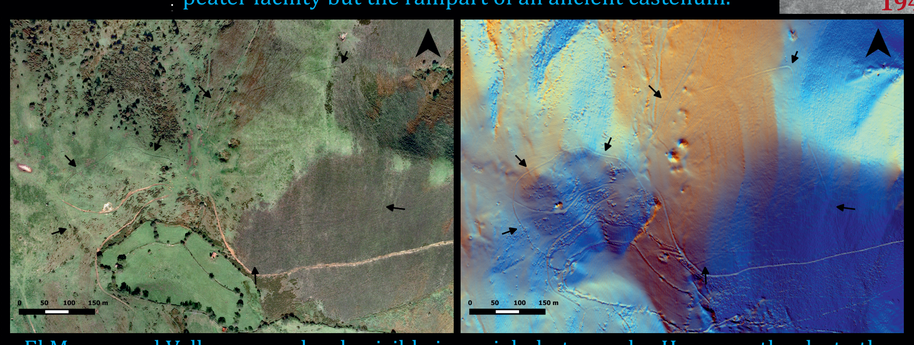
Modern reforestation plans are also hidding our archaeological heritage in rural areas. Although its rampart is about 1 m height, Monte dos Trollos is nowadays practically invisible.



Diacronic perspective. While reviewing Picu El Outeiro we realised that the inner enclosure was not part of the TV repeater facility but the rampart of an ancient castellum.



Cornado was wrongly identified as an Iron Age hillfort in the past. LiDAR technology and aerial historical photography allow us to contemplate its playing card layout.



El Mouru and Valbona are clearly visible in aerial photography. However, thanks to the LiDAR technology we can detect their defensive perimeter in further extension.

You can download this poster here: http://[...]

Please, use the URL for citations

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